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ABSTRACT

A number of cultural and neurophysiological variables were studied to examine their relationship with sex differences in spatial ability. Five paper-and-pencil spatial ability tests were administered to a group of 50 male and 51 female college students, with approximately equal numbers for each sex being left- or right-handed and left- or right-eye dominant. Four of the five tests showed significant sex differences. Electroencephalographic recordings from the left and from the right parietal regions were obtained with the subjects at rest and while solving four different spatial tasks. Questionnaires were also administered regarding the extent of participation and the extent of enjoyment for 25 spatially-oriented activities. Other questionnaires concerned trait anxiety and independence versus family influence. Although the neurophysiological variables were correlated with spatial test scores, they had very little potential for explaining sex differences in spatial test performance: but the cultural variables in the study did show promise in explaining those differences. (Author/CTM)

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TOWARD EXPLAINING SEX DIFFERENCES IN SPATIAL ABILITY: AN INVESTIGATION OF SELECTED CULTURAL AND NEUROPHYSIOLOGICAL FACTORS

a paper presented
at the Annual Meeting
of the

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by

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Abstract

Differences in performance of spatial tasks between males and females have been consistantly demonstrated. The focus of this study is on the question of whether observed sex differences in spatial ability can be explained by either selected cultural variables, neurophysiological variables, or a combination of these variables. Measures were obtained for handedness, eyedness, cerebral hemisphere used while processing spatial tasks, participation and enjoyment in activities related to visual-spatial skills, family influence in decision making, anxiety, and five paper and pencil tests of spatial performance. The findings suggest that the neurophysiological variables have very little potential for explaining sex differences in spatial test performance. The cultural variables in this study appear to have the most promise in helping explain sex differences in spatial ability.

TOWARD EXPLAINING SEX DIFFERENCES IN SPATIAL ABILITY: AN INVESTIGATION OF SELECTED CULTURAL AND NEUROPHYSIOLOGICAL FACTORS

One of the most consistently observed cognitive differences between men and women is in the area of spatial abilities. Most research reports show males, starting in early adolescence, performing better than females on spatial tasks with the gap widening as subjects approach adulthood. Whether these differences stem from neurophysiological differences or from differences in socialization and training is unclear. There is a well-established body of literature relating spatial skills to the information processing activities of the right cerebral hemisphere. This generalization, however, applies most appropriately to right-handed people. Less is known about hemisphere specialization of left-handers. Also, the suspicion lingers that being cross-dominant, right-eyed and left-handed, for example, may be associated with perceptual problems. Is it possible that some of the explanation for sex differences in spatial ability may be found in systematic study of these variables? This investigation examines the relationships among a set of neurophysiological, cultural, and spatial ability variables. More specifically, relationships are examined among measures of handedness, eyedness, hemisphere functioning, background experiences, anxiety, and five different tests of spatial performance. The focus of this study is on the question of whether observed sex differences in spatial ability can be explained by either selected cultural variables, neurophysiological variables, or a combination of these variables.

Background and Related Literature

Recent reviews by Fennema (1974), Maccoby & Jacklin (1974), and Harris (1978) cite numerous studies in which males outperform females

on tests of spatial ability. This superiority appears over a wide variety of tasks ranging from simple form boards to the ability to do mental work on visual images and to maintain a sense of direction and orientation. Sherman (1971) cites earlier research suggesting that most spatial tests are manifestations of a single underlying spatial factor. Smith (1964), on the other hand, distinguished between relatively simple spatial-analytic abilities and the more gestalt-like ability to perform transformations on visual images, to mentally move, turn, twist, rotate, or otherwise visualize objects in new positions and combinations. It is this latter ability to mentally manipulate a visual gestalt which, Smith asserts, is most relevant to other cognitive processes; and it is this form of spatial ability on which men and women are most sharply differentiated.

Explanations for the observed differences in spatial ability between men and women have included genetic, hormonal, neurological, and cultural causes. Each of these is treated in some detail in the review by Harris (1978). Since a host of work (Lauria, 1973; Milner, 1974; Sperry, Gazzaniga, & Bogen, 1961; Wada, 1949; Galin & Ornstein, 1973; and numerous others) has established specialization of the left cerebral hemisphere for language and the right hemisphere for spatial tasks, it is natural to expect explanations of male-female differences in spatial ability to make use of the concept of hemisphere specialization. Buffery & Gray (1972) and Levy, Trevarthen, & Sperry (1972) offer evidence that females are less well lateralized than males, and argue that the presence of language functions in the right hemisphere may interfere with spatial reasoning.

The theory of cerebral conflict, however, is softened by the notion that the two halves of the intact brain share more functions

and work in a more integrated way than the studies of hemisphere dominance lead us to believe (Gazzaniga & LeDoux, 1978). Recent work in Copenhagen using cerebral blood flow shows a Z-like pattern of activity on the surface of each hemisphere during reading (Lassen, Ingvar, & Skinhøj, 1978).

The thought that neurological organization may help explain sex differences in spatial ability extends to the concepts of hand and eye dominance. The typical pattern of hemisphere specialization is true for about 96 percent of right-handed people. For left handers, however, about 70 percent have left hemisphere speech; 15 percent have right hemisphere speech; and 15 percent have speech represented in both hemispheres (Rasmussen & Milner, 1975). In a study of 2400 high school students, Yen (1975) failed to find left-handed females scoring differently from right-handed females on spatial tests; but left-handed males did exhibit a decrement in performance over right-handed males.

Interest in eye dominance, particularly crossed dominance between eyedness and handedness, was stimulated by Orton's (1937) contention that incomplete lateralization was at the base of many cases of reading disability. Annett (1970) used questionnaire data to demonstrate that hand preference can better be described as a continuous, rather than a discrete, variable. Walls (1951) published an impressive analysis of eye dominance phenomena concluding that eye dominance is essentially a habitual preference of one eye for sighting, thus avoiding binocular conflict in centering on objects in the environment for closer inspection. By unwittingly depending on one eye for the directional aspects of orientation, smooth binocular coordination is achieved. The non-dominant eye tracts, or moves in tandem with, the

sighting eye. The chosen eye has nothing to do with the neurological organization of the individual.

A more recent review by Porac & Coren (1976) supports the conclusions of Walls. The Porac & Coren review along with an unpublished review by Hiscock and Kinsbourne (no date) cite numerous studies which fail to support the crossed-dominance theory of learning and perceptual disabilities.

From the studies suggesting a neurological basis for sex differences in spatial ability, it seems clear that hemisphere specialization will continue to be an important variable in investigations of this issue. Handedness, because of direct neurological links to cerebral dominance, will also be a variable of interest. It is more difficult to support inclusion of eye dominance in such studies. The cross-dominance theory of disabilities is far from dead; however, since females are more likely to be cross-dominant than males (Porac & Coren, 1978), continuing collection of data relevant to the crossed-dominance issues may be warranted.

The role of cultural variables in the development of differential spatial abilities in males and females has been included in Lauran Harris's (1978) comprehensive review. A number of studies are cited by Harris showing that boys, more than girls, from very early ages, exhibit patterns of play that include exploration, manipulation, movement, body contact, and dynamic use of space. For example, boys tend to play farther away from their mother than girls; and nursery school boys are reported to have made greater use of a half-acre nursery complex than girls (Harper & Sanders, 1975).

Sherman (1967) cites several additional studies which lend credence to the effect of early experience and training on the development of spatial abilities. By high school age, marked differences in

participation in activities which may help develop spatial abilities are noted. While 62 to 77 percent of high school males have participated to some extent in electrical repairs, woodworking, model building, or auto repair, only 10 to 14 percent of the females report participation in these activities (Flanagen, Davis, Dailey, Shaycroft, Orr, Goldberg, & Neyman, 1964). In a more recent survey of secondary school students (Erlick & LeBold, 1977), almost half of the female respondents reported themselves as being below average in mechanical ability, compared to only 17 percent of the male respondents.

In reviewing socialization studies, one must be impressed with the early appearance of sex differences characterizing males as more independent, interactive, exploratory, and manipulative. A strong logical link could be forged between such experiences and the development of skills in maintaining orientation in physical space and in visualizing unseen structures. Given this expectation, it seems surprising that more studies of the relationship of experience to spatial abilities have not been attempted.

This abbreviated review of the literature notes the consistency with which sex differences in spatial ability have been observed and suggests that the ability to manipulate mental images is one of the more central components of spatial skill. The role of the right hemisphere in spatial perception is reviewed, and the idea is offered that differential degrees of lateralization for males and females may be part of the explanation of male-female differences in spatial ability. Related questions about the role of handedness and eye dominance are raised. In addition, attention is drawn to the notion that experience and acculturation may play a critical role in the development of spatial abilities. These themes provide the background for the choice of variables and the design of the present study.

Method

Subjects

The initial sample for this study was 249 students enrolled in introductory psychology at Purdue University who elected this project to earn required credit for participation in an experiment. Sign-up sheets forced an equal distribution of right- and left-handed students in the initial sample.

Based on further screening, a final sample of 101 students was obtained. The final sample was selected to include approximately equal students in each cell of a sex by eyedness by handedness classification. The cell frequencies are shown in Table 1.

Table 1

Number of Subjects in the Final Sample in Each Sex by Eyedness by Handedness Group

	Female		Male	
Group	Left Handed	Right Handed	Left Handed	Right Handed
Left-Eyed	13	12	12	12
Right-Eyed	12	14	14	12

In addition, the proportion of students in technical and non-technical programs of study was equated for each cell.

Instruments

The instruments used in this study are described below:

Briggs and Nebes Handedness Questionnaire (Briggs & Nebes, 1975). This questionnaire asks subjects to show on a five-point scale ranging from "always left" to "always right" their hand preference for 12 activities, e.g., write a letter, throw a ball, etc.

ABC Vision Test (Mills, 1929). This test, published by the Psychological Corporation, is the most widely used sighting test for establishing eye dominance (Porac & Coren, 1976). The test requires the subject to pick up a simple cardboard cone with both hands, place it with the wide end over both eyes, and name a visual target held by an examiner 10 feet away. The cone is unconsciously aligned so that the target is fixated with the dominant eye, this eye being readily detected by the examiner. Three trials were given, and the score was recorded as "right" or "left."

Keystone Telebinocular. This optical testing instrument was used to obtain two measures:

(1) Acuity eye dominance is determined by monocular testing of each eye using the Keystone card 5110 titled Snellen Far-Point Acuity Test. The eye with the greater acuity was recorded as the dominant eye.

(2) Depth perception is measured using Keystone card DB 6D titled A Test for Stereopsis.

Sighting Eyedness (Hole). This second measure of sighting eye dominance requires the subject to pick up a 5 x 8 inch card with a small hole in the middle and look through the hole at the examiner. The eye used for the task is recorded as the dominant eye.

Spatial Experience Questionnaire (SEQ) (McDaniel, Guay, Ball, & Kolloff, 1978). This instrument was developed especially for this study and was used to obtain four measures:

(1) Extent of participation is determined from ratings on a four-point scale ranging from "very often" to "never" on 25 spatially-oriented activities, e.g., playing chess and drawing.

(2) Extent of enjoyment is determined from rating the same 25 activities on a four-point scale ranging from "very much" to "none."

(3) Self-perceived ability is a self-estimate of the difficulty involved in performing four spatial visualization tasks, e.g., constructing a mental map of a city.

(4) Family influence is a measure to determine whether the respondent depended on a particular family member or on himself or herself in four developmental situations, e.g., choice of high school subjects.

Trait Anxiety Inventory (Spielberger, Gorsuch, & Lushene, 1970). The trait anxiety scale consists of twenty statements that ask the respondents to describe how they generally feel. Subjects respond to each item (e.g., "I lack self confidence") on a four-point scale ranging from "almost never" to "almost always." The trait anxiety scores were obtained from records of concurrent testing performed independently of the present study. Trait anxiety data were available for 78 of the 249 subjects in the initial sample and for 38 of the 101 subjects in the final sample.

Spatial Ability. Five paper-and-pencil spatial ability tests were administered in this study. These tests were selected from the results of a pilot study analyzing self-reports of students' mental processes while working items from nine spatial tests (Guay, McDaniel, & Angelo, 1978). On the basis of the pilot study, two tests were chosen for use that required analytical-type mental processing: The Minnesota Paper Form Board and Visualization of Developments. Three tests that required more gestalt-like mental processing were also chosen for use: Shepard-Metzler Rotations, Visualization of Rotations,

and Visualization of Views. Each of the five tests is described below:

(1) Revised Minnesota Paper Form Board (MPFB): A 32-item version (odd items from Form MA) was employed. Each item requires the subject to recognize a form that can be made by fitting together stimulus pieces (see Figure 1).

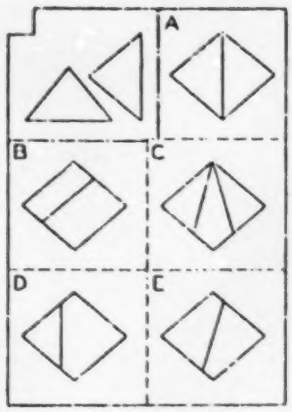

Figure 1. Illustration of an MPFB Test item.

(2) Shepard-Metzler Rotations (S-M): This test measures the subject's ability to mentally rotate objects in three-dimensional space (Shepard & Metzler, 1971). The test has 20 items, each item requiring the subject to observe a stimulus object to the left of a vertical line (see Figure 2) and then select two of the drawings (A through D) that represent the stimulus object rotated in space.

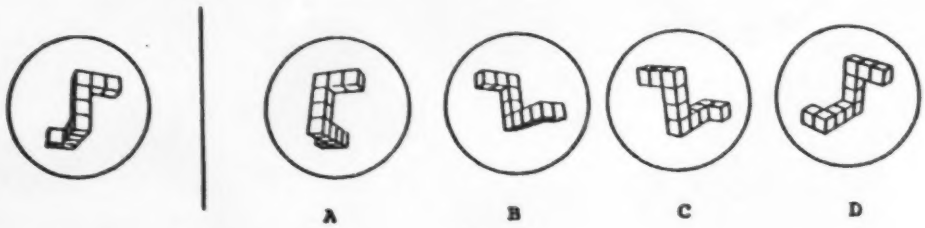

Figure 2. Illustration of an S-M Test item.

(3) Visualization of Developments (DEV): This test consists of 12 items designed by Guay (1977) to measure the ability to mentally develop a three-dimensional form when presented with a representation of the stretched-out surfaces. Each stretch-out shows the inside surfaces of a three-dimensional object. Subjects must select from five alternatives the picture of the object that would be formed by the pattern shown (see Figure 3).

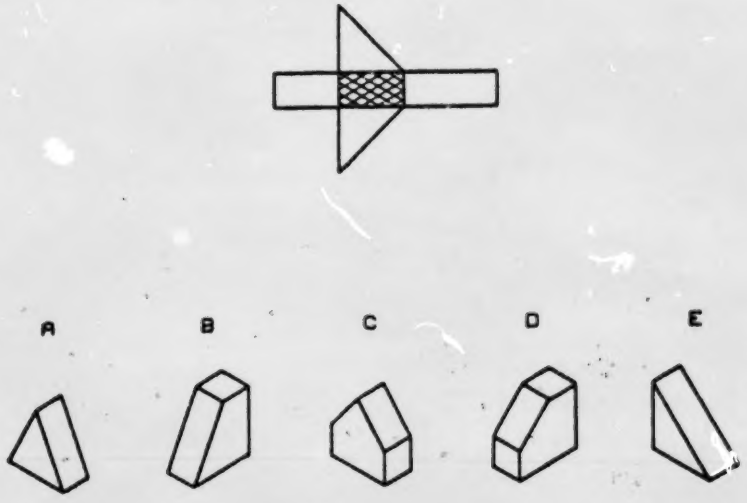

Figure 3. Illustration of a DEV Test item.

(4) Visualization of Rotations (ROT): This test consists of 30 items designed by Guay (1977) to measure the ability to mentally rotate a three-dimensional object in space. In the pilot study already cited, this test exceeded the Shepard-Metzler in eliciting gestalt processing. For each item of this test (see Figure 4), the subject is required to determine how a stimulus figure has been rotated, then rotate a new stimulus figure in the same fashion and select

from among five drawings the position of the figure after rotation.

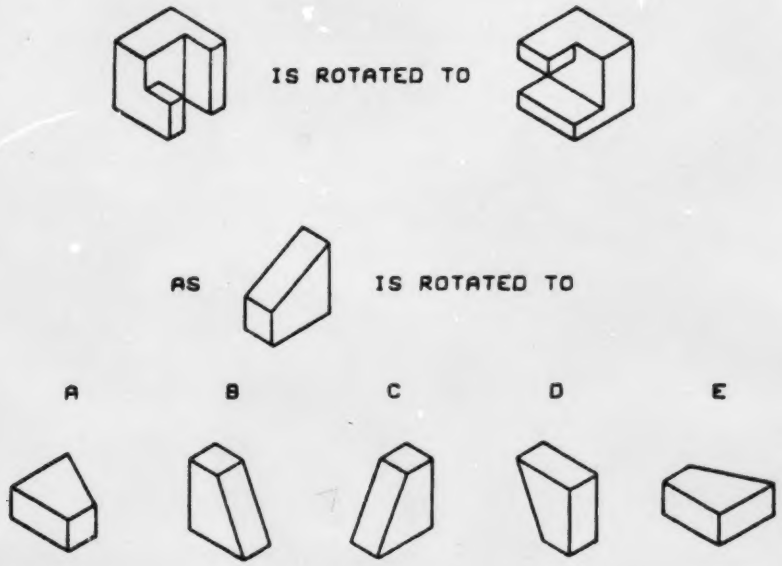

Figure 4. Illustration of an ROT Test item.

(5) Visualization of Views (VIEW): This test was designed by Guay (1977) to test the ability to imagine oneself moving around a stationary object to obtain a particular view of it. The test contains 12 items. Each item presents an object positioned in the middle of a "glass box." A black dot at one of the corners of the "glass box" indicates the viewing position. The subject is required to picture what the object looks like from the viewing position and select from among five drawings the appropriate view (see Figure 5).

Hemisphere Functioning. The data were derived from the analysis of electroencephalographic (EEG) recordings made while subjects were resting and while they were solving four different spatial tasks. The analysis yielded a baseline EEG index (resting) and four task

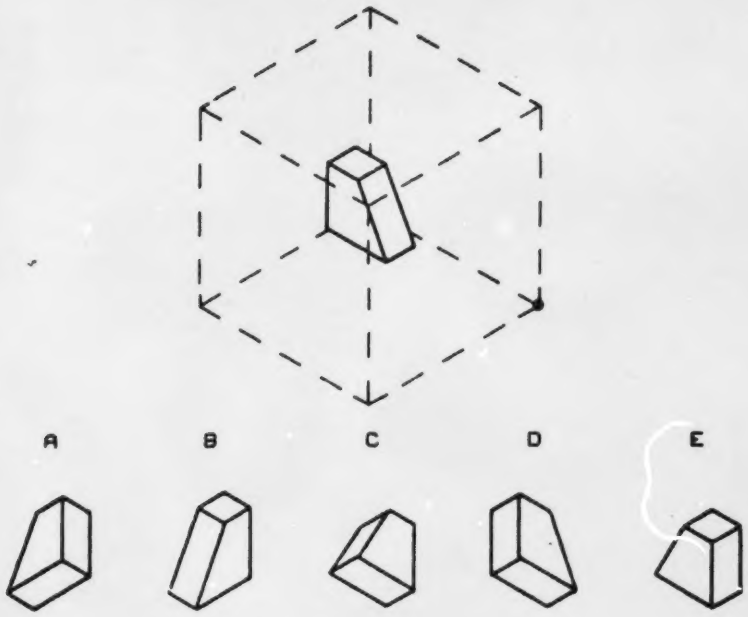

Figure 5. Illustration of a VIEW Test item.

specific EEG indices (one each for the MPFB, S-M, DEV, and ROT Test) for each subject. All five indices were mean log ratios of alpha powers found between the right parietal and left parietal regions of the brain. The EEG recordings were obtained in a shielded, sound-attenuated EEG room at the Purdue University Student Hospital and were supervised by a trained EEG technician. A special computer system was used to convert the analog recordings to alpha powers, and to further convert the alpha powers into mean log ratios.

Procedure

Three different types of sessions were used to collect the data in this study: (1) screening sessions, (2) spatial testing sessions, and (3) EEG sessions. Each session lasted approximately one hour. All 249 subjects in the initial sample participated in a screening

session, but only the 101 subjects in the final sample participated in a spatial testing session and an EEG session.

Fifteen screening sessions were conducted. The screening sessions were used to administer the Handedness Questionnaire, S-M Test, MPFB Test, SEQ, ABC Test, and to measure acuity eye dominance and depth perception with the Keystone Telebinocular. Approximately 16 subjects participated in each screening session.

Twelve spatial testing sessions were held. These sessions were used to administer the DEV Test, ROT Test, and VIEW Test. During these sessions, groups varying in size from 2 to 19 were tested. The 101 participants in these spatial testing sessions were selected because they each had a desirable combination of eyedness and handedness for his/her sex.

Each of the 101 subjects who participated in a spatial testing session also participated in an EEG session. One EEG session was scheduled for each subject. This session was used to record the raw EEG data necessary to determine the relative left/right cerebral activity of the subject while he/she rested and while he/she solved four different types of spatial test items (i.e., MPFB, S-M, ROT, and DEV). The Hole Test, measuring sighting eye dominance, was also administered during this session.

Results

Sex Differences in Spatial Ability

Significant sex differences in spatial ability were found for the S-M, DEV, ROT, and VIEW Tests, but not for the MPFB Test. The means and standard deviations for the male and female groups on the five spatial tests are presented in Table 2.

Table 2
Means and Standard Deviations
of Spatial Test Scores for the Total Sample
and for Males and Females Separately

Group	n	Mean	S.D.
		MPFB Test	
Male	127	22.79	4.31
Female	122	22.25	3.99
Total	249	22.53	4.16
		S-M Test	
Male	127	27.92	7.09
Female	122	21.08	5.76
Total	249	24.57	7.31
		DEV Test	
Male	50	8.36	2.71
Female	51	6.63	2.31
Total	101	7.48	2.65
		ROT Test	
Male	50	22.28	4.78
Female	51	16.78	5.79
Total	101	19.50	5.97
		VIEW Test	
Male	50	9.08	2.78
Female	51	6.92	2.85
Total	101	7.99	3.00

Note. Maximum scores: MPFB = 32, S-M = 40, DEV = 12, ROT = 30, and VIEW = 12.

T-tests were run on the observed data. These tests revealed, as expected, that males scored significantly higher than females on the S-M Test, $t(247) = 8.34$, $p < .001$; DEV Test, $t(99) = 3.46$, $p < .001$; ROT Test, $t(99) = 5.20$, $p < .001$; and the VIEW Test, $t(99) = 3.85$, $p < .001$. Tests for homogeneity of variance were run to check the data. For the S-M Test, the male variance was found to be significantly greater ($p < .025$) than the female variance. As a result, a

t'-statistic was computed for the S-M scores: $t'(240) = 8.37$. As before, the results indicate a significant ($p < .001$) male advantage.

Potential Explanations of the Sex Differences

The cultural variables self-perceived ability, trait anxiety, enjoyment, and familial influence included in this study were found to have some promise in helping to explain sex differences in spatial test performance. None of the neurophysiological variables included in this study were found to have significant promise in explaining sex differences.

These conclusions are based on the findings of a regression analysis adapted especially for this study by Dr. George McCabe, Head of Statistical Consulting, Purdue University. This regression approach involves the evaluation of the percentage of shared variance between spatial test performance and sex that is also shared by a particular variable or combination of variables. Specifically, this statistical procedure involves (1) constructing a primary series of linear regression models including one or more cultural variables, one or more neurophysiological variables, and a combination of cultural and neurophysiological variables; (2) defining a secondary series of linear regression models exactly like the primary series except for the inclusion of the sex term; and (3) testing for the equivalency of the companion models using an F-statistic. Tests yielding low F-statistics (high probabilities) of equivalency are desired. The lower the F-statistics (higher the probabilities), the more the variable(s) included in the primary models also share(s) the shared variance between spatial test performance and sex. As a result, the lower the F-statistics, the more likely the variable(s) has (have) the potential for explaining sex differences in spatial test performance.

Two statistical procedures were utilized to help build efficient and effective linear regression models: (1) R^2 analyses for all possible combinations of a set of variables and (2) stepwise multiple linear regression techniques. Forward regression was used to arrive at the F-statistics evaluating the equivalency of the companion models.

When these regression procedures were applied to the observed data, regression models composed of the variables self-perceived ability, trait anxiety, enjoyment, and/or familial influence were found to have some promise for explaining sex differences in spatial test performance. When linear regression models containing only neurophysiological variables were tested, they were found to have very little potential for explaining sex differences. As a result, when mathematical models containing both cultural and neurophysiological variables were evaluated, they were found to have some promise, but not any more promise than the same models without the neurophysiological variables.

The lack of potential of neurophysiological factors in explaining sex differences can be illustrated by the test of a primary regression model for the DEV Test. This primary model contained the variables handedness, sighting eyedness (hole), acuity eyedness, and task specific EEG. The R^2 for the model in predicting DEV Test performance was found to be .074. When the secondary model, which was exactly like the primary model except for the inclusion of the sex variable, was constructed, the R^2 for the secondary model was found to be .212. The test for the null hypothesis that the two models are equivalent led to the rejection of the null, $F(1,88) = 15.11$, $p < .001$. The results suggest that the combination of variables in the first model has no promise in explaining the observed sex differences in DEV Test performance.

The models found in this study to have the most potential for explaining sex differences were those which yielded small F-statistics (high probability levels). As was previously mentioned, these models contained a combination of the cultural variables self-perceived ability, trait anxiety, enjoyment, and/or familial influence. The most promising models found in this study, and their potential for explanation across the four spatial tests yielding significant sex differences, are presented in Table 3.

It should be noted that the amount of shared variance between sex and spatial test performance that is also shared by a particular variable is largely dependent upon both the strength of relationship between the variable and sex and the strength of relationship between the variable and spatial performance. The strength of these relationships for each cultural and neurophysiological variable is presented in Table 4. Note that significant sex relationships were found in this study for self-perceived ability, trait anxiety, and enjoyment, and that each of these variables was also found to have the most promise in explaining sex differences for those tests that the variables were most highly correlated with.

Discussion

The notion that sex differences in spatial ability in favor of males exists (e.g., Harris, 1978; Maccoby & Jacklin, 1974) was strongly supported by the results of this study. In addition, the hypothesis that the magnitude of sex differences would be greater for more-gestalt spatial tests than for more-analytic spatial tests (Smith, 1964) was also supported by the findings. The more-gestalt tests, i.e., the S-M, ROT, and VIEW Tests, yielded the largest and most significant sex differences.

Table 3

Results of F-tests for Equivalency of Selected Cultural Models

Spatial Performance Being Predicted	Variables in the Model	R^2 Model	R^2 Model+ Sex	F Between Models	df	p
S-M	Self-Perceived Ability, Familial Influence, and Trait Anxiety	.126	.187	4.25	1,58	.044
	Self-Perceived Ability and Trait Anxiety	.086	.206	11.04	1,73	.001
	Familial Influence and Trait Anxiety	.079	.162	5.74	1,58	.020
	Familial Influence, Trait Anxiety, and Interaction	.093	.177	5.84	1,58	.019
	Participation and Trait Anxiety	.010	.192	15.98	1,71	.000
	Enjoyment, Familial Influence, and Trait Anxiety	.089	.174	5.93	1,58	.018
DEV	Self-Perceived Ability, Familial Influence, and Trait Anxiety	.338	.454	5.92	1,29	.022
	Self-Perceived Ability and Trait Anxiety	.157	.264	4.79	1,33	.036
	Familial Influence and Trait Anxiety	.329	.454	6.59	1,29	.016
	Familial Influence, Trait Anxiety, and Interaction	.352	.468	6.12	1,29	.020
	Participation and Trait Anxiety	.146	.272	5.69	1,33	.023
	Enjoyment, Familial Influence, and Trait Anxiety	.372	.473	5.32	1,29	.029
ROT	Self-Perceived Ability, Familial Influence, and Trait Anxiety	.287	.307	.81	1,29	.377
	Self-Perceived Ability and Trait Anxiety	.267	.303	1.75	1,33	.195
	Familial Influence and Trait Anxiety	.224	.269	1.79	1,29	.192
	Familial Influence, Trait Anxiety, and Interaction	.318	.353	1.51	1,29	.229
	Participation and Trait Anxiety	.166	.253	3.84	1,33	.058
	Enjoyment, Familial Influence, and Trait Anxiety	.289	.314	1.10	1,29	.304
VIEW	Self-Perceived Ability, Familial Influence, and Trait Anxiety	.194	.215	.76	1,29	.389
	Self-Perceived Ability and Trait Anxiety	.189	.199	.39	1,33	.536
	Familial Influence and Trait Anxiety	.166	.202	1.31	1,29	.260
	Familial Influence, Trait Anxiety, and Interaction	.282	.309	1.07	1,29	.310
	Participation and Trait Anxiety	.284	.312	1.29	1,33	.263
	Enjoyment, Familial Influence, and Trait Anxiety	.305	.319	.56	1,29	.461

Table 4

Correlation Coefficients Between the Cultural and Neurophysiological Variables and Sex and Between the Cultural and Neurophysiological Variables and the Five Spatial Test Scores

	Variable	Sex	Spatial Test: MPFB	S-M	DEV	ROT	VIEW
Neuro-physiological	Handedness	a	-.02(249)	.15***(249)	.08(101)	.01(101)	.16**(101)
	Sighting Eyedness (A-B-C)	-.07(249)	.05(249)	.14**(249)	-.04(101)	.13(101)	.11(101)
	Sighting Eyedness (Hole)	.05(101)	-.02(101)	-.01(101)	-.10(100)	-.14*(100)	-.11(100)
	Acuity Eyedness	.01(249)	-.09(249)	-.11**(249)	-.12(101)	-.03(101)	-.06(101)
	Depth Perception	-.04(249)	.11**(249)	.04(249)	-.01(101)	-.05(101)	.04(101)
	Baseline EEG	.11(87)	-.14*(87)	-.07(87)	-.02(86)	-.15*(86)	.01(86)
	Task Specific EEG	b	-.06(92)	.03(92)	-.13*(92)	.00(92)	a
Cultural	Participation	.05(245)	.05(245)	.04(245)	.18**(100)	.08(100)	-.05(100)
	Enjoyment	.14**(247)	.13**(247)	-.04(247)	.13*(101)	.01(101)	-.11(101)
	Self-Perceived Ability	-.39***(248)	.14**(248)	.37***(248)	.37***(100)	.45***(100)	.37***(100)
	Familial Influence	.07(200)	.03(200)	-.15**(200)	-.16*(78)	-.00(78)	-.02(78)
	Trait Anxiety	.31***(78)	-.09(78)	-.08(78)	-.37**(38)	-.47***(38)	-.39***(38)

Note. Handedness ranges from +24 to -24, with +24 indicating maximum right handedness. Eyedness is coded 0 or 1, with 0 left and 1 right. Depth perception ranges from 0 to 12, with 12 indicating good depth perception. EEG normally ranges from +.30 to -.30, with +.30 indicating strong right cerebral activity. Both participation and enjoyment range from 0 to 75. Self-perceived ability ranges from 0 to 8, with 8 indicating high self-perception. Familial influence ranges from 0 to 8, with 0 indicating lack of family influence. Trait anxiety ranges from 0 to 80, with 0 indicating high anxiety. Numbers in parentheses indicate the number of cases used to compute the coefficients. Sex is coded 0 or 1, with 0 male and 1 female.

*p < .10, one-tailed test.

**p < .05, one-tailed test.

***p < .01, one-tailed test.

[a] Not available.

[b] -.07(92) for MPFB EEG
-.08(92) for S-M EEG
-.10(93) for DEV EEG
-.12(93) for ROT EEG

In regard to potential explanations of the sex differences, the results suggest that several cultural factors investigated in this study have some potential, but all neurophysiological factors investigated in this study have very little potential, for explaining sex differences in spatial test performance. This conclusion is consistent with the literature suggesting cultural explanations (e.g., Harris, 1978; Sherman, 1974) and inconsistent with the literature suggesting neurophysiological explanations (e.g., Buffery & Gray, 1972; Witelson, 1976). This conclusion does not suggest that neurophysiological factors are not related to spatial test performance. It does, rather, suggest that neurophysiological factors are not highly related to sex differences in spatial test performance. The results of this study (see Table 4) clearly show that many cultural and neurophysiological variables are related to spatial test performance, but only selected cultural factors are strongly related to the variable sex.

The cultural variables in this study that appear to have the most promise in helping to explain sex differences in spatial test performance are self-perceived ability, trait anxiety, enjoyment, and familial influence. Note that these variables were found to have the most promise (i.e., yielded the largest probabilities) in explaining sex differences for the ROT and VIEW Test performance. This was particularly evident when different combinations of the four cultural variables were evaluated (see Table 3). Remember, the ROT Test represents the class of spatial tests that elicits visualization-type of gestalt processing, whereas the VIEW Test represents the class of spatial tests that elicits orientation-type of gestalt processing. The generalizability of the potential for explanation between the visualization- and orientation-type of spatial tasks was one of the most notable findings of this study.

On the other hand, one of the most disappointing findings of this study was the lack of generalizability of the potential for explanation to the S-M Test. The S-M Test, like the ROT Test, was classified as a spatial test eliciting visualization-type of gestalt processing and found to elicit large sex differences. Therefore, it was expected that the same variables that have the potential to explain sex differences for one test would have the potential to explain sex differences for the other test. The lack of generalizability of the potential for explanation between the ROT Test and the S-M Test was investigated. The lower magnitude of relationship between the selected cultural variables and S-M performance, when compared to the magnitude of relationship between the same variables and either ROT or VIEW performance (see Table 4), was identified as the major problem.

Although the data suggest that the self-perceived ability variable has the most promise of all the variables investigated for explaining sex differences, this finding must be interpreted with caution, since it is impossible to know for sure what the self-perception scores collected in this study actually measured. It seems logical to assume that the reported self-perceptions were influenced largely by the fact that all the subjects were reminded of the male advantage when they signed up for the study. However, feedback from experiences in doing spatial thinking, including taking one or more spatial tests, and complex sex-role belief systems may have also influenced the reported self-perceptions. It will remain a task for future research to identify the potential that each factor underlying self-perceptions of ability has in influencing sex differences in spatial test performance. Because of the difficulty in interpretation, the self-perceived ability variable was used sparingly during the model building stage of data analysis.

The potential that trait anxiety, enjoyment, and familial influence have for explaining sex differences in spatial test performance is best exemplified by the data observed for the combination of these three variables on ROT and VIEW Test Performance (see Table 3). For the ROT Test, the combination of the three variables yielded an F-statistic of 1.10 and a probability of .304; and for the VIEW Test, the same combination yielded an F-statistic of .56 and a probability of .461.

It should be emphasized in closing that the findings of this study do not imply in any way that the cultural variables trait anxiety, enjoyment, and familial influence either independently or in combination cause sex differences in spatial ability. These variables may contribute to the sex differences (i.e., they may have some potential for explaining the sex differences), but the correlational nature of this study does not allow one to reach the absolute conclusion that these variables cause, contribute to, or help explain sex differences in spatial ability. The results of this study do, however, allow one to conclude with relative certainty that all the neurophysiological variables and one or more of the cultural variables included in this study do not cause, contribute to, or help explain sex differences in spatial ability.

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